Demographic trends in less and least developed countries: Convergence

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ORIGINAL RESEARCH

Demographic trends in less and least developed countries: Convergence or divergence?

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Abstract

Many scholars share the assumption that demographic patterns in the world are converging over time. The present study analyses the temporal trends of specific parameters of mortality and fertility—together with certain socio-economic indicators—in 95 less and least developed countries during the period 1990–2015 and discusses whether mortality and fertility trends are convergent or divergent. We apply dynamic factor analysis and cluster analysis of trajectories to macro-data from major international sources. The results show that a large number of countries have a convergent trend in mortality, but sub-Saharan African countries affected by the HIV–AIDS epidemic show non-monotonic temporal trends. Trends in fertility are delayed and unclear and depend on individual attitudes and levels of women's empowerment. Fifty-two out of the 95 observed countries are collocated in similar mortality and fertility groups. Finally, countries at an advanced economic stage made the best improvements, while the least developed ones retained their deep pre-existing inequalities.

Keywords Mortality · Fertility · Less developed countries · Converging trends · Dynamic factor analysis · Cluster analysis

Introduction

In recent years, many less and least developed countries (LDCs; United Nations [UN] 2019) have witnessed both a rise in life expectancy and a decline in fertility. Theories of social change, which are based on empirical findings, share the assumption that demographic patterns in various societies are converging (Coughlin, 2000; Hendi, 2017; La Croix et al., 2002). According to the convergence theory, countries become more similar in terms of their demographic characteristics as they achieve similar levels of socio-economic development.

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Nevertheless, these processes may coexist, with considerable heterogeneity in living and socio-economic conditions in various countries (Gabrielli et al., 2018).

In many population studies, the concept of convergence is linked to the demographic transition theory (Leibenstein, 1954; Notestein, 1953). Based on observations of the experiences of LDCs, this theory anticipates that fertility and mortality rates will vary over time in a predictable and uniform manner. It generally assumes that LDCs would follow a path of economic and social progress similar to the one already observed in more developed countries in the decades 1870–1930. This process gives rise to changes in demographic regimes, changes that can be briefly described in terms of a transition from a situation in which mortality and fertility are high to a regime of a relatively low level of these two variables. Such changes have important consequences for population growth and age structure modifications.

The convergence hypothesis has also been complemented by the theory of modernisation, which describes a world that is moving toward a new 'demographic equilibrium' (Wilson, 2001) and which refers more specifically to the tendency of a society to acquire the economic, political, social, and cultural characteristics typical of modernity, such as individualism and rationalism. According to the modernisation theory, economic, political, and social developments contribute to homogeneity, or towards a restricted set of alternatives (Berry et al., 2014; Jones, 1997). Modernisation is also closely related to the concept of economic development, while the social dimension of modernisation manifests itself in phenomena related to demographic change, such as a decline in fertility and mortality, urbanisation, extensive migration processes, and a transformation in the status of women, that is, 'female empowerment' (Gabrielli et al., 2018).

Chesnais (1997) and Oeppen (1999) were amongst the scholars of population dynamics who dealt with convergence explicitly, while Heuveline (1999) considered the consequences of convergence on a regional and on a global scale. Similarly, the UN base their projections on the assumption of convergence, forecasting a homogeneous world in which almost all demographic variability tends to disappear (Wilson, 2001).

Despite the assumptions that demographic rates across regions would converge, the empirical evidence for this is contradictory. Many countries are extremely unequal on many dimensions, and this is likely to be related to demographic variables.

Other researchers have emphasised that convergence is far from being a uniform, irreversible, and inexorable trend (Guillén, 2001); rather, it is a fragmented, incomplete, discontinuous contingency, and is in many ways a contradictory and puzzling process (Gilpin, 2000). They argue that globalising trends do not affect countries uniformly (Berry et al., 2014; Ghemawhat, 2003). Moreover, it has been shown that there is resistance, and even a backlash, in some parts of the world. This is something that the recent economic crisis has accelerated.

In light of the above-mentioned issues, the aim of our research is to analyse trends in specific demographic parameters with regard to mortality and fertility in 95 LDCs (and some of their socio-economic characteristics), to assess whether demographic behaviours are indeed converging, or whether marked differences persist. In particular, we are interested in observing countries that in recent years have been badly

affected by HIV–AIDS, countries that display a strong decline in child mortality rates, and countries whose fertility rates are stalling.

Convergence and demographic transition: an overview of the literature

The convergence hypothesis has increasingly attracted the interest of researchers, along with the theoretical issues of demographic transition. Studies based on these concepts have so far produced intriguing but sometimes conflicting results. Here, we consider some recent analyses related to our topic. We first describe the relevant studies that focus on mortality only and those focusing on fertility only. We then summarise the ones that consider both fertility and mortality, and finally, the ones that have included the socio-economic context in their observations.

In terms of mortality and health, empirical research has generally confirmed the assumption that life expectancy levels are rising and converging. In fact, a number of studies have demonstrated that starting from the 1920s, a convergence in life expectancy levels was occurring in many countries (Becker et al., 2003, Easterlin, 2000; Neumayer, 2003, 2004; Pradhan et al., 2003; Ram, 2006).

Other research has shown that, following a homogeneous pre-transitional phase, demographic transition generates multidimensional geographic and socio-economic heterogeneity, until the reappearance of a homogeneous and convergent post-transitional phase (Balabdaoui et al., 2001).

McMichael et al. (2004) suggested a recurring transition process of health, while Moser et al. (2005) found that, despite the overall improvements in global life expectancy at birth during the second half of the twentieth century, this convergence has been replaced since the late 1980s by a divergence of some regions of the world (e.g., many Eastern European countries and many sub-Saharan countries [Grigoriev et al. 2014]). Vallin and Meslé (2004) stressed that these countries seem to be exceptions to convergence in the first stage of health transition: "Not only did a number of conflicts and other forms of political unrest in recent decades put individual countries outside the scheme of Omran's epidemiologic transition (1998), but in particular sub-Saharan countries seem to remain more systematically outside the process for a variety of reasons" (Vallin & Meslé, 2004: 19). A comparison of the increase in the pace of life expectancy observed in these countries reveals two different situations: the first group of countries enjoyed fairly steady progress, while the second was hit by a severe HIV–AIDS epidemic.

With reference to fertility trends, Casterline (2001) modelled the pace of decline in less developed countries from 1950 and found a significant level of inter-country and intra-regional variation. Wilson and Pison (2004) suggested that, despite significant changes in the middle of the distribution, the overall range did not decrease.

Strulik and Vollmer (2015) applied the method of 'convergence clubs,' (Wilson, 2001, p.376) which derived from the Solow model in economics. This refers to groups of countries in which the trends are similar, even if they differ from the more general patterns of convergence (Sala-i-Martin, 1996; Solow, 1956). It relies on the idea of conditional convergence, according to which the equilibrium eventually

reached by each club depends on its initial position, and/or on other specific factors. Lehmijoki and Pääkkönen (2006) assumed that convergence should arise in homogeneous demographic samples of countries, and that economic growth should be affected by demographic growth.

Researchers on modernisation and convergence have revealed notable changes in fertility in the majority of LDCs experiencing transitions from high to low fertility, and in its inverse relationship with indicators of socio-economic development (Hendi, 2017; Hirschman, 1994; Murthi, 2002; Notestein, 1953). Examining the fertility transition across countries in four different income categories, Wang et al. (2016) showed whether and how social, economic, political and population policy factors have very different effects on the decline in fertility rates. Political freedom is found to play a role in shaping people's perceptions of fertility. A diminution in political freedom in upper middle-income countries exerts downward pressure on fertility rates, while it has a positive effect on fertility rates in lower middle- and low-income countries. Population policies, measured by the contraception prevalence rate, have been found to be effective in reducing the total fertility rate (TFR) in upper middle-income, lower middle-income, and low-income countries.

With regard to studies that have considered both fertility and mortality, Coale and Cotts Watkins (1986), in describing the transition in Europe, presented the main trends in fertility, mortality, and population growth. Borges (2018) summarised the movement from diverse combinations yielding low growth rates (moderate fertility and mortality) to high growth potential, achieving a uniform combination of very low fertility and mortality (i.e., low to negative growth).

Wilson (2001) noted that in the second half of the twentieth century, the share of the world's population who were living under conditions of declining fertility and rising life expectancy increased steadily; he described this process as "global demographic convergence" (Wilson, 2001, p.375). Wilson observed that social and demographic change had progressed more rapidly than economic development and argued for demographic convergence.

Dorius (2008) showed that the observed variation in inter-country fertility decline for much of the second half of the last century pointed to divergence, rather than convergence, and that the TFRs of countries did not begin to converge until around 1995. He further speculated that the convergence in health, wealth, and life expectancy may be explained by the consistent link between economic and social development, while noting that fertility is less consistently linked to development. So, he argued for demographic divergence in fertility and convergence in mortality.

More recently, Wilson (2011) suggested that most demographic change over the past half-century has occurred along a *main sequence* of demographic transition, and that the great majority of the world's population were engaged in a process of convergence. He pointed out that when it comes to health transition, the world is not a single demographic system, but instead is divided by deep fault lines into a number of blocks, each of which has its own distinctive life expectancy trajectory. Moreover, Berry et al. (2014, p.388) demonstrated that "countries have not evolved significantly closer or similar to one another, although groups of countries, based on their core-periphery status or membership in trade blocs, exhibit increasing internal convergence and divergence from one another."

Other authors have described the demographic transition as a process with causal effect, by which fertility declines as a result of a decline in mortality.[1] According to this approach, mortality decline would act as a stimulus for demographic responses, for instance rational decisions amongst populations concerning fertility (Kirk, 1996). The demographic behaviour of populations is clearly linked to the social and economic inequalities they face, since the material conditions and expectations people experience impact birth and death outcomes and the propensity to migrate (Borges, 2018).

From a different starting point and including the socio-economic context, researchers taking a cross-country perspective have shown that convergence in demography might occur mainly among countries with comparable socio-economic and environmental characteristics (Mishra et al., 2011).

Using a set of different variables, Angeli and Salvini (2009) carried out a descriptive analysis of the population characteristics of countries with low and medium Human Development Index levels. While acknowledging that some exceptions in the convergence process emerged in terms of the mean values of the parameters, they emphasised the strong link between social, economic, and demographic development. Patarra (1994) agreed that demographic rates might, in the long-term, converge, though this hypothesis is moot in terms of the explanations of the transformations, which result from distinct social processes.

Convergence is largely used as a framework for studying income inequality transition (Srinivas, 2014). However, as Oeppen (1999, p.213) put it, "despite this, until 1990, there seems to have been no attempt to address convergence in a formal way in population policy context."

The idea of convergence is widely debated in the economics literature, where it stems from the neoclassical model of growth. Most scholars here talk about a *single unified framework*, outlining the fact that the contemporary era of sustained economic growth—the era of Malthusian stagnation—had mostly characterised the process of development (Galor, 2011; Lee, 1997). This approach also considers the influence of economic evolution on demographic processes and transition.

On the other hand, Farina and Ortensi (2011) showed that demographic indicators do not share a similar economic development. Countries that were at a more advanced stage economically improved the most, while in the least developed countries there remained deep pre-existing inequalities, for example in sub-Saharan countries. While progress, regarding mortality, health conditions, education and

[1] Demographic transition comprises different stages. Stage I is characterised by high birth and death rates, and a low rate of population growth. Stage II is characterised by a high and stationary birth rate, a rapidly declining death rate, and a very rapid increase in population. Stage III presents low levels of both mortality and fertility; consequently, the rate of growth is close to 0, and population reaches stationarity. In more recent years, scholars have outlined two additional stages, referring to these as a second demographic transition. Stage IV presents the lowest level of fertility (and a declining and ageing population, the latter a consequence of greater longevity). Stage V is characterised by a further increase in survival rates due to the advance of studies on the human genome (Lestaeghe 2010; Omran 2005; van de Kaa 2004). We must point out that this new research, which complements the classic demographic transition theory, has not been applied to LDCs, which do not yet have ageing populations. Consequently, the additional stages do not affect the prospect of convergence in LCDs.

contraception are directly related to the level of development, the economic dimension is not as closely related to the level of fertility.

This general framework of demographic convergence/divergence suggests that education, gender equality, female labour force participation, and health services assume an important role in development and demographic change (Masia et al., 2018). In particular, education is the fundamental factor that affects the decline in both mortality and fertility rates through the reduction in the desired number of children and their improved care (Gabrielli & Paterno, 2014; Murthi, 2002; Paterno, 2010). The mechanism is the same with regard to the female labour force and gender equality, while health service improvements influence contraceptive use and the health status of children and mothers (Cohen, 1998; De Ferranti et al., 2004).

Our research fits into this theoretical and empirical framework. Our original contribution to the international debate lies in the fact that we examine recent trends in the socio-demographic parameters of 95 LDCs to determine whether convergence is taking place, and whether clusters of countries based on time trajectories of demographic behaviours can be identified. Depending on the characteristics of available data and after identifying homogeneous groups of countries in their general mortality and fertility dynamics, we aim to test the following research hypotheses:

Hp1 Convergent trends in both mortality and fertility levels have been occurring over time across LDCs since the mid-twentieth century. However, specific dynamics may determine the opposite.

Hp2 Mortality and fertility dynamics have monotonic shapes across LDCs. However, specific events (such as wars, epidemics, political, and economic crises, and so on) may determine the opposite.

Hp3 LDCs are included in the most disadvantaged/advantaged clusters in terms of mortality and are equally collocated in terms of fertility. This path should occur if the different stages of demographic transition encompass both mortality and fertility dynamics.

Hp4 A similar convergent trend should occur amongst countries with comparable socio-economic characteristics (such as educational and occupational gender parity, and in a health, wealth, and development context).

Data and methods

Data

The analyses are carried out on 95 countries (statistical units) with a population of at least one million in 2015, and which have been identified by the UN (2019) as being LDCs. These have very heterogeneous demographic and socio-economic characteristics and provide different sources of data. However, we use two main international data sources: World Bank and UN (see Table 1 in the Appendix). Both institutions provide recommendations to countries to harmonise and improve the quality of their official statistics. The World Bank has defined and measured the statistical capacity of countries to meet users' needs for good quality official statistics. The World

Table 1 List of variables included in the analyses and relative abbreviations and data sources

Variables	Acronyms	Data sources
Analysis of mortality		
Prob. of death among males aged 15–60	${}_{45}q_{15}^{M}$	United Nations
Prob. of death among females 15–60	${}_{45}q_{15}^{F}$	United Nations
Under five mortality	${}_{5}m_{0}$	World Bank
Maternal mortality rate	MMR	World Bank
HIV–AIDS prevalence	HIV–AIDS	World Bank
Immunisation for diphtheria, pertussis and tetanus	DPT3	World Bank
Access to improved sanitation	AIS	World Bank
Analysis of fertility		
Adolescent fertility rate	${}_{4}F_{15}$	World Bank
Total fertility rate	TFR	World Bank
Age at childbearing	MACB	United Nations
Contraceptive prevalence rate	CPR	World Bank
Gender parity index in secondary school enrolment	GPI	World Bank
Female labor-force participation rate	$LFPR^{F}$	World Bank
Analysis of mortality and fertility		
Human Development Index	HDI	United Nations
Income index	IC	World Bank
Level of education	AYS	World Bank

bank's website allows visitors to compare countries' statistical capacity over time through the Statistical Capacity Index (the SCI; for details see https://www.worldbank.org/en/data/statistical-capacity-building/overview and http://opendatatoolkit.worldbank.org/en/supply.html). When updated data are released, countries are usually advised to review their previous data only if the quality has improved.

We considered the SCI scores of the 95 countries in 2019 and compared them with those of the referent macro-area: the ratio between each SCI country score and correspondent SCI macro area score is at least 60% in 85 out of 95 countries, while 10 have the worst SCI ratios or lack information. (Data are not shown here for reasons of space, but they are available on request). However, all 95 countries have been included in the final analysis to provide a more extensive overview of mortality and fertility, because no significant differences emerge when the 10 countries referred to above are considered as supplementary units in the analyses.

Unfortunately, it was not possible to consider the years prior to 1990 because there were too many missing data in the considered variables. Thus, the observed times are the 6 years 1990, 1995, 2000, 2005, 2010, and 2015. Macro data are used to perform descriptive analysis, because only these kinds of data allow such a large number of countries to be observed over an extended period.

We analyse the fertility and the mortality processes separately through their main indicators. The analyses are conducted on the same set of countries in each of the years for which complete data are available. Because both fertility and mortality are associated in the analysis with the most commonly correlated socio-economic

Table 2 Mortality**:** Quality indices of factorial representation. Proportion of total variance (trace of indicated covariance matrices) explained by selected components in PCA of St

Quality index	Description	Value
It (St)	St = average covariance matrix over times	0.945
$I(S_{1990})$	S_{1990} = covariance matrix in year 1990	0.898
$I(S_{1995})$	S_{1995} = covariance matrix in year 1995	0.937
$I(S_{2000})$	S_{2000} = covariance matrix in year 2000	0.958
$I(S_{2005})$	S_{2005} = covariance matrix in year 2005	0.959
$I(S_{2010})$	S_{2010} = covariance matrix in year 2010	0.948
$I(S_{2015})$	S_{2015} = covariance matrix in year 2015	0.951
*Ii (*Si)	*Si = covariance matrix of xij	0.958
Iit (Sit)	Sit = covariance matrix of differential dynamic of units	0.848

variables, we can discern different patterns in the LDCs studied. Unfortunately, it is not possible to consider a wider number of indicators (such as age at first child, child epidemics and socio-political indicators of instability, conflict, and climate changes) due to the lack of consistent data.

Data sources and abbreviations for demographic and socioeconomic variables are included in Table 1. For the analysis of mortality, the variables consist of ten yearly indicators: probability of death at ages 15–60 both for men ($_{45}q_{15}^{M}$) and women ($_{45}q_{15}^{F}$); mortality of children under age five ($_5m_0$); maternal mortality ratio (MMR); prevalence of HIV–AIDS (HIV–AIDS); Human Development Index (HDI); immunisation coverage for diphtheria, pertussis, and tetanus (DPT3); access to improved sanitation (AIS); income index (IC); and education index (AYS). For the analysis of fertility, nine yearly indicators have been selected: total fertility rate (TFR); adolescent fertility rate ($_4F_{15}$); contraceptive prevalence (CPR); Human Development Index (HDI); gender parity index in secondary school enrolment (GPI); age at childbearing (MACB); income index (IC); education index (AYS); and labour force participation amongst women ($LFPR^{F}$).

The HDI is a composite index made of three standardised sub-indices (Appendix Table 10) and is correlated with some of the other indicators considered in the analysis (such as adult and child mortality incidence, but mainly with income and education (see Appendix Table 11). Also, TFR is somehow correlated to the adolescent fertility rate (see Appendix Table 13). However, correlation is easily handled in the following statistical models, whose aim is to provide synthetic and not directly observed indicators measured over more dimensions. To address the problem of collinearity, some preliminary analyses (available on request) were performed by including different sets of variables, in particular dropping HDI for mortality analysis and HDI and TFR for fertility analysis. The preliminary results lead to similar quality indices of factorial representation (Tables 2, 6) and correlation matrixes between variables and the first two components of factorial analyses (Tables 3, 7) for mortality and fertility respectively. When considering cluster analyses, no different classification occurs for mortality in respect to those obtained when considering also HDI, while the lack of TFR determines a different classification of countries for

Table 3 Mortality: Correlation matrix between variables and the first two components

Variables[a]	Component 1	Component 2
${}_{45}q_{15}{}^{M}$	− 0.82	0.40
${}_{45}q_{15}{}^{F}$	− 0.85	0.42
${}_{5}m_{0}$	− 0.51	0.80
MMR	− 0.48	0.84
HIV–AIDS	− 0.96	− 0.28
DPT3	0.22	− 0.71
AIS	0.49	− 0.71
HDI	0.49	− 0.77
IC	0.41	− 0.71
AYS	0.27	− 0.78

[a]See Table 1

Source: Our elaboration on data of World Bank and United Nations (for details see Appendix Table 10)

fertility. To provide a more comprehensive picture of the articulated scenario, both HDI and TFR have been included in the final analysis.

The methodological approach

As the paths of mortality and fertility differ significantly over space and time, we apply dynamic factor analysis and cluster analysis of trajectories to evaluate at the macro level the main demographic trends in LDCs in the 1990–2015 period. We do not make causal inferences with our method. It allows for a descriptive and explorative analysis of data.

Since the 1970s, researchers have become increasingly interested in multiway data, classified according to more than two dimensions (the classic units × variables). Many methods of using such data have been developed, in particular for data classified according to three dimensions (Coppi, 1994; Coppi & Bolasco, 1989). However, few of these methods allow for a specific statistical treatment of the third dimension, when it is time, which is usually considered symmetrically with respect to the other two dimensions. Furthermore, when observations over time are very few and time series models lack significance, a descriptive approach can be considered.

Dynamic factor analysis (DFA) was an Italian proposal that was developed initially in the 1970s and later in the 1990s (Coppi & Zannella, 1979; Facioni et al., 2019) to handle multiway data classified as units × variables × times, from a descriptive point of view. In DFA, the same units and quantitative variables are observed at each point time. The method considers the time dimension explicitly, in the sense that it is addressed by specific statistical tools. The method is indeed based on the joint application of factorial analysis (to explore the relationships among units and variables) and regression over time (to analyse the time dynamic of units and variables). Factorial analysis and regression are applied to particular means, calculated via a specific mode of classifying and reading the data by countries, or time or social-demographic indicators.

A brief point about data representation needs to be made before explaining DFA. Data may be represented by a matrix X (IT,J), which is obtained by collapsing the single matrices units × variables $X(I, J)_t$ observed at each point in time, over each other. In the present study, the units are the countries, variables are the indicators of mortality and fertility, and times are the 6 years of observation. The generic element of X(IT, J) is x_{ijt} with $i = 1, \ldots, I$, $j = 1, \ldots, J$, $t = 1, \ldots, T$, where i represents the country index, j the indicator index, and t the year index.

Let us define **S** as the overall covariance matrix of X(IT, J). According to the three criteria of data classification (unit, variable, and time), three sources of variation are considered and modelled in DFA: the first derives from the joint interaction of variables and units, a sort of structural variability or *static*, which is the undertone of the overall variability averaged over time. The second and the third refer to the way time interacts with the units and variables, respectively. In particular, the variables dynamic is represented by the variability over time of the mean of each variable $x_{.jt}$[2]; the units dynamic is represented by the time changes of units' barycentres over variables. When the focus is on the relationships between variables and time, as it is in the present study, to give more relevance to variables' dynamics, the units' dynamic over time is considered as differential or net with respect to the mean time changes of each variable—if it strengthens the change of the variables or if it moves in other directions over time, weakening or even contrasting the overall dynamics.

In DFA, the overall variability summarised in **S** is linearly decomposed in the three sources of variability described above, namely static, dynamic of centres ($x_{.jt}$), and units' differential dynamic (the net dynamic of single units, when the centres' trends have been subtracted), according to the following (Coppi & Zannella, 1979; Corazziari, 1999):

$$\boldsymbol{S} = * \boldsymbol{S_i} + * \boldsymbol{S_t} + \boldsymbol{S_{it}}$$

where $*\boldsymbol{S_i}$ is the covariance matrix of the centres $x_{ij.}$ representing the static source of variation, $*\boldsymbol{S_t}$ is the covariance matrix of $x_{.jt}$, and $\boldsymbol{S_{it}}$ is the covariance matrix representing the differential dynamics of units, after subtracting the mean variables dynamic and the static source of variation.

The DFA consists of four models, each of which employs a specific strategy in approaching the three sources of variation. We use the model that allows us to focus on the variability and dynamics of the demographic indicators. The dynamic of each country over time is observed in its net time variation with respect to the overall variation of the averaged socio-demographic indicators: we observe whether each country strengthens, weakens, or even reverses the patterns of the indicators over time.

With regard to the time evolution of demographic indicators' means on each occasion, the DFA model uses a linear regression model for each indicator j, where the independent variable is time. The parameters are obtained by ordinary least squares, with the classic assumptions about residuals $e_{.jt}$: $\mathrm{cov}[e_{.jt}, e_{.j't'}] = \sigma^2_j$, if $j = j'$ and $t = t'$, and zero otherwise.

[2] A dot is used to indicate the operation of averaging data according to the dimension.

A factorial analysis is then applied to the covariance matrix $\mathbf{S_t} = {}^*\mathbf{S_i} + \mathbf{S_{it}}$, also obtainable as the sum of the covariance matrix of indicators by year, divided by the total number of years. The variability of the indicators averaged over time x_{ij}, that is, the first source of variation called *static*, is then represented in the factorial analysis by projecting their matrix ${}^*_c\mathbf{X_i} = \{x_{ijt} - x_{.j.}\}$ centred with respect to the $x_{.j.}$s, on the factorial plane, thereby obtaining the mean position of each country. By projecting the matrices ${}_c\mathbf{X_t} = \{x_{ijt} - x_{.jt}\}$ centred on each time point, the trajectories over time of each country can be compared with their corresponding mean position, allowing us to evaluate their differential or net time evolution.

The projected trajectories of the units on the factorial plane are usefully summarised by a specific statistical analysis of groups: the cluster analysis of trajectories (Carlier, 1986; Coppi et al., 2010). When studying trajectories, two types of distance between countries can be considered: a mean of the comparison (differences) between two countries in each year (mean instantaneous distance), and a mean of the comparison of the variations between adjacent years of each country (mean unfolding distance) with corresponding variations amongst the other countries, for each pair of countries. In the present study, a mean of the two above distances was considered and the Ward method of cluster analysis was applied and confirmed by a final K-means cluster analysis based on the barycentre of the clusters of the better Ward partition (Kaur & Kaur, 2013). The obtained clusters are homogeneous in terms of the levels and of the dynamics of the considered quantitative indicators.

The interpretation of our results is based on the correlation coefficients between the indicators and the axes of the factors' plane, obtained by a principal component analysis of $\mathbf{S_t}$. If the clusters move toward the centre of the plane (which characterises the overall dynamic of the system of data) homogeneity is increasing, that is, convergence is underway. By contrast, if the clusters move away from the centre, heterogeneity is increasing for the countries in that cluster. Indexes of the goodness of fit of each source of variation in each of the models are also provided. They are calculated as the ratio between the trace of the modelled covariance matrix of the specific source of variation, and the corresponding observed trace for each of the covariance matrices described above.

Results

Mortality and health

The results of the DFA indicate that the first two components of the factor analysis explain a large portion of the variability ($I_t = 94.5\%$; see Table 2), and that the best represented times are the third and the fourth ones (2000 and 2005, with percentages of 95.8 and 95.9, respectively).

With regard to the correlation between variables and factors (see Table 3), we find a strong negative correlation for the first component with both the probabilities of death at adult ages (separately for men and women) and the prevalence of HIV–AIDS. The correlation with under-five mortality is also negative, but weaker. The second component is strongly and positively correlated with

Table 4 Mortality: Time regression analysis[a] of centers of units (overall index of regression fitness *It = 0.96)

Variables[b]	R-square	Least Square Estimates			
		Constant	(Std. error)	Slope coefficient	(Std. error)
${}_{45}q_{15}{}^{M}$	0.685	1.123	(4.6E−2)	− 3.5E−2	(1.2E−2)*
${}_{45}q_{15}{}^{F}$	0.471	1.114	(6.7E−2)	-3.3E−2	(1.7E−2)*
${}_{5}m_{0}$	0.995	1.559	(2.1E−2)	−0.160	(5.4E−3)
MMR	0.976	1.521	(4.6E−2)	−0.149	(1.2E−2)
HIV–AIDS	0.272	0.753	(0.225)	−7.1E−2	(5.7E−2)*
DPT3	0.941	0.842	(2.2E−2)	4.5E−2	(5.6E−3)
AIS	0.998	0.825	(4.5E−3)	5.0E−2	(1.2E−3)
HDI	0.992	0.833	(8.3E−3)	4.8E−2	(2.1E−3)
IC	0.964	0.914	(9.2E−3)	2.456	(2.4E−3)
AYS	0.984	0.726	(1.9E−2)	7.826	(4.9E−3)

[a]It could be possible a regression of higher order but given the very little change over time, as indicated by the slope, with respect to the mean level of the variable, a conservative position has been preferred, with a uniform model (simple model of order one) for every regression

[b]See Table 1

Source: Our elaboration on data of World Bank and United Nations (for details see Appendix Table 10)

maternal mortality and under-five mortality. The correlation with adult mortality (separately for men and women) is also positive, but the values are low. A strong negative correlation of the second component is shown with Human Development Index, level of education, access to improved sanitation, immunisation for DPT3, and income. In summary, the first component assumes the meaning of mortality and morbidity (increasing values of the components mean decreasing mortality and morbidity rates), while the second component represents the sanitary conditions and the overall economic, health, and educational status of the observed countries; decreasing values of the components mean an improvement in such conditions).

Before commenting on the factorial results, we discuss the overall dynamics of the centres, to explain the cluster of units' trajectories projected on the factorial plane. The dynamic of centres ($x_{.jt}$) over time is described through time regression of a suitable order, as indicated in Table 4. The overall index of fitness for this type of variability is good (96%).

For all variables (as well as for the variables in the analysis of fertility), a simple linear regression model in *t* is fitted. (Elaborations are not shown here, but they are available upon request). The average indicators of mortality decrease over the period, especially child mortality, while the indicators of human development, DPT3 immunisation, and access to improved sanitation increase. The mean prevalence of HIV–AIDS has a non-monotonic shape: it first increases then decreases, with a peak in 2000 (the third occasion). Since 2003, an impressive fall in positive diagnoses of HIV–AIDS was seen shortly after the introduction of Highly Active Antiretroviral Therapy (HAART) in low-income and middle-income countries (Ford et al. 2011).

The projection of countries on each occasion over the factorial plane provides their trajectories over time; the differential ones with respect to the centres x_{jt} dynamics are described by regression. Clustering the trajectories using the hierarchical Ward method leads us to choose a partition formed by six clusters. The sequence of the clusters expresses the relative ranking according to the mean value of under-five mortality levels (from the highest, corresponding to cluster **a**, to the lowest, corresponding to cluster **f**). We decided to consider this specific index to order the clusters, because more than others (such as adult mortality) it is a clearer indicator of development.

Table 5 contains a list and the number of LDCs that have been included in each cluster of mortality, while, for reasons of space, we show the median values of variables and values of the first two components for each cluster by year in Appendix Table 12. A brief description of each cluster of mortality can be found below.

A geographic concentration is quite evident for four of these clusters, while two (clusters **d** and **f**) include countries located in heterogeneous macro areas (Table 5). With the sole exception of cluster **e**, which registered an increase in adult mortality rates, the six clusters register (in the period 1990–2015) a general decrease of the median values concerning mortality and an increase of the median values concerning access to sanitation, the Human Development Index, and level of education (Appendix Table 12).

Cluster **f** is the largest of the clusters. Nearly half of the countries are included in it (45 countries located in different macro areas). Its main features are the lowest levels of under-five mortality, of adult mortality for men and women, and of HIV–AIDS prevalence since 1990. At the same time, it assumes the highest values of immunisation for DPT3, of access to improved sanitation, of the Human Development Index, of the income index, and of the education index. The improvements in the period 1990–2015 are less evident because the cluster had good levels of the observed indicators from the beginning.

Cluster **e** includes five South African countries. In 1990 it was characterised by the second lowest levels of adult, child, and maternal mortality (just higher than those of cluster **f**), and by levels of Human Development Index, education, and income that were comparable with those of cluster **f**. However, the main feature of cluster **e** is the largest increase of the prevalence of HIV–AIDS, which reached its peak in 2010 (23.1%). As a consequence, while child mortality assumes the second lowest value (after cluster **f**), the levels of male and female adult mortality drastically increases from 1990 to 2005 and assumes the highest values in 2015 (463.2‰ and 412.2‰ for men and women, respectively). Countries included in this cluster reveal the lowest improvements in the Human Development Index, income index, and education index.

Cluster **d**, which contains 19 countries, is geographically strongly heterogeneous (African, Latin American, and Asiatic countries). Even if it displays significant delays in the health transition compared to cluster **f**, it has the second lowest adult mortality levels for men and women and the second lowest prevalence of HIV–AIDS. Moreover, it observes the best improvements, particularly in access to sanitation and in the income index, and the second-best improvement in immunisation coverage for DPT3.

Table 5 Mortality**:** List of 95 analysed countries by cluster of mortality (K-means method)

Cluster	Countries	N
a	Afghanistan, Angola, Burkina Faso, Burundi, Chad, Congo Dem Rep., Eritrea, Ethiopia, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Sierra Leone	15
b	Cameroon, Central African Republic, Cote d'Ivoire, Kenya, Mozambique, Rwanda, Tanzania, Uganda	8
c	Malawi, Zambia, Zimbabwe	3
d	Bangladesh, Benin, Bolivia, Cambodia, Congo, Gabon, Gambia, Ghana, Haiti, India, Madagascar, Mauritania, Myanmar, Nepal, Pakistan, Papua New Guinea, Sudan, Togo, Yemen	19
e	Botswana, Lesotho, Namibia, South Africa, Swaziland	5
f	Algeria, Argentina, Bahrain, Brazil, Chile, China, Colombia, CostaRica, Cuba, Dominican Republic, Ecuador, Egypt, El Salvador, Guatemala, Honduras, Indonesia, Iran, Iraq, Jamaica, Jordan, Kuwait, Lebanon, Malaysia, Mauritius, Mexico, Morocco, Nicaragua, Oman, Panama, Paraguay, Peru, Philippines, Qatar, Saudi Arabia, Singapore, Sri Lanka, Syrian Arab Republic, Thailand, Trinidad and Tobago, Tunisia, Turkey, United Arab Emirates, Uruguay, Venezuela, Vietnam	45

Source: Our elaboration on data of World Bank and United Nations (for details see Appendix Table 10)

Cluster **c** comprises three East African countries. It is characterised by a prevalence of HIV–AIDS similar to that of cluster **e** in the first 3 years (1990, 1995, and 2000) and by the highest values of adult mortality, which reached their peak in 2000 (620.8‰ for men and 575.7‰ for women). However, the prevalence of HIV–AIDS significantly decreases in the next periods, even if it is still present in 2015 (12.9%). Also, child mortality reaches the highest value in 1990, but shows the most evident decrease in the period 1990–2015. This cluster is also characterised by intermediate positions for the other variables. Despite a trend in countertendency in recent years, the three countries still have much to do to narrow the accumulated gap.

Cluster **b**, which includes eight Central-East African countries, has the second highest levels of adult (just below the levels of cluster **e**), child, and maternal mortality (just below the levels of cluster **a**). The improvement in access to sanitation, which nevertheless remains below that observed in the previous clusters, is accompanied by a significant reduction in HIV–AIDS prevalence after 2000 and in the maternal mortality rate.

Lastly, cluster **a** includes 15 countries mainly located in Central-West Africa (plus Afghanistan). These countries show the highest level of child mortality and maternal mortality since 1990. Conversely, the prevalence of HIV–AIDS is low and adult mortality (amongst men and women) is constantly decreasing. Despite the largest immunisation progress and a reduction in both the child and maternal mortality rates in the period 1990–2015, the immunisation index is still the lowest in 2015, together with the values regarding access to sanitation, Human Development Index, income index, and education index.

Based on the DFA method, the differential dynamic of median centres of clusters is represented in Fig. 1. Generally speaking, the trajectories of the clusters on the factor plane show a trend toward the average situation: the paths over time of each cluster converge towards the centre of the axes of the factorial plane. In other words,

the dynamics of the countries included in such clusters show a slow reduction in their differentials with respect to the observed variables.

The only exception is represented by cluster **e**, which tends to step away significantly from the centre due to the sharp increase in HIV–AIDS, which in recent years seems to have taken a backward step. Also, cluster **b** and **c** assume divergent (even though they are not so wide) trends at the beginning of the period but show significant improvements after that. Cluster **d** appears almost stable, while cluster **f** is the most oriented toward the centre of the axes.

Fertility

Our results regarding fertility can be synthesised as follows. The first two components of DFA explain 79.9% (Table 6) of the variability of the phenomenon, less than in the mortality analysis, where the variables are slightly more numerous. For fertility, the fourth and the fifth times are better represented (2005 and 2010, with percentages of explained variability of 82.3 and 81.5, respectively).

In terms of the correlation of the two components with the active variables (Table 7), positive values for the first component indicate better situations in terms of the Human Development Index, income index, education index, contraceptive prevalence, and gender parity index in secondary school enrolment, while negative values correspond with higher total and adolescent fertility rates. In summary, the values for the variables measuring development are opposed to those measuring fertility behaviours: with increasing levels of development, fertility levels generally decline.

The second component is positively linked to a reduction in the age at childbearing, while a negative value corresponds to higher female labour force participation. This result confirms that the emancipation of women is inversely related to the cadence of fertility.

To better explain the trajectories of countries over the factorial plane, it is necessary to look at the overall dynamic of the data. Table 8 shows the time regression parameters and shows that the overall index of fitness for this type of variability is 99%. The two indicators of fertility (total fertility rate and adolescent fertility rate) are decreasing over time, while the indicators that describe development (i.e., Human Development Index, gender parity index in secondary school enrolment, contraceptive prevalence, income index, education index, and labour force participation for women) are increasing on average over the period. (Elaborations are not shown here, but they are available upon request.)

Based on these dynamics and clustering the trajectories, the hierarchical Ward method defines a partition formed by six clusters, as obtained in the mortality analysis presented above. The labels of the clusters (**a**, **b**, **c**, **d**, **e**, and **f**) express their ranking based on the median value of TFR (from the highest to the lowest, from cluster **a** to cluster **f**), and therefore generally describe the demographic transition stage and the level of socio-economic development.

Table 9 reports the list and the number of LDCs that have been included in each cluster of fertility, while, for space reasons, we show the median values of

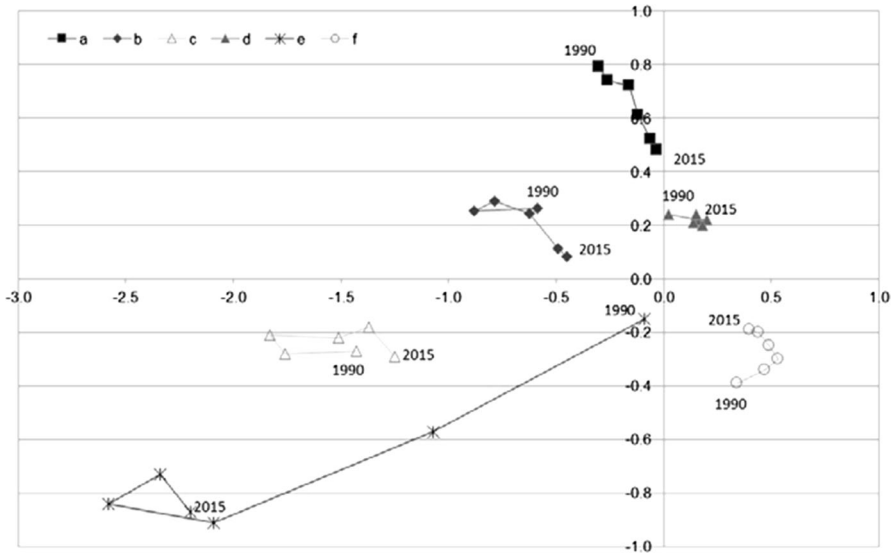

Fig. 1 Differential dynamics of median centres of clusters. Health and mortality. Factors' scores. Source: Our elaboration on data of World Bank and United Nations (for details see Appendix Table 10)

Table 6 Fertility: Quality indices of factorial representation. Proportion of total variance (trace of indicated covariance matrices) explained by selected components in PCA of StProportion of total variance (trace of indicated covariance matrices) explained by selected components in PCA of St

Quality index	Description	Value
It (St)	St = average covariance matrix over times	0.799
$I(S_{1990})$	S_{1990} = covariance matrix in year 1990	0.760
$I(S_{1995})$	S_{1995} = covariance matrix in year 1995	0.797
$I(S_{2000})$	S_{2000} = covariance matrix in year 2000	0.806
$I(S_{2005})$	S_{2005} = covariance matrix in year 2005	0.824
$I(S_{2010})$	S_{2010} = covariance matrix in year 2010	0.815
$I(S_{2015})$	S_{2015} = covariance matrix in year 2015	0.796
*Ii (*Si)	*Si = covariance matrix of xij	0.824
Iit (Sit)	Sit = covariance matrix of differential dynamic of units	0.452

variables and values of the first two components for each cluster by year in Appendix Table 14. A short description of each cluster of fertility, according to these two tables, is reported below.

In the analysis of fertility, the countries are better distributed among clusters than in the analysis of mortality (Table 9): 4 clusters assume comparable sizes (clusters **b**, **c, e**, and **f** are made up of 21, 17, 25, and 15 countries, respectively) while clusters **a** and **d** include only 9 and 8 countries, respectively. In the overall period 1990–2015, the six clusters show a reduction of the median values of both TFR and adolescent fertility rate, and a general improvement of the others observed indicators

Table 7 Fertility**:** Correlation matrix between variables and the first two components

Variables[a]	Component 1	Component 2
${}_4F_{15}$	−0.84	−0.35
TFR	−0.94	0.13
MACB	−0.29	0.64
CPR	0.88	−0.39
GPI	0.71	−0.23
$LFPR^F$	−0.43	−0.62
HDI	0.91	0.04
IC	0.80	0.18
AYS	0.86	−0.15

[a]See Table 1

Source: Our elaboration on data of World Bank and United Nations (for details see Appendix Table 10)

Table 8 Fertility: Time regression analysis of centres of units (overall index of regression fitness It = 0.99)

Variables[a]	R-square	Least Square Estimates			
		Constant	(Std. error)	Slope coefficient	(Std. error)
${}_4F_{15}$	0.998	1.283	6.974E−3	−8.086E−2	1.791E−3
TFR	0.977	1.272	2.303E−2	−7.765E−2	5.912E−3
MACB	0989	1.012	7.067E−4	−3.436E−3	1.815E−4
CPR	0.989	0.718	1.625E−2	8.070E−2	4.172E−3
GPI	0.994	0.903	4.351E−3	2.762E−2	1.117E−3
$LFPR^F$	0.933	0.934	9.780E−3	1.875E−2	2.511E−3
HDI	0.992	0.833	8.253E−3	4.775E−2	2.119E−3
IC	0964	0.914	9.201E−3	2.456E−2	2.363E−3
AYS	0.984	0.726	1.918E−2	7.826E−2	4.925E−3

[a]See Table 1

Source: Our elaboration on data of World Bank and United Nations (for details see Appendix Table 10)

(Appendix Table 14). Interestingly, the only exception is represented by the labour participation for women; this decreases from 1990 to 2015 in clusters **a**, **b**, and **c**, and increases in clusters **d**, **e**, and **f** (Appendix Table 14).

Clusters **a** and **b** are the most distinct geographically, as they include only sub-Saharan countries (with the exception of Afghanistan and Yemen, which are in cluster **b**).

Cluster **a** comprises five West African countries, two Central-South African countries (Angola and Chad), and two East African countries (Mozambique and Uganda). It is characterised by a strong delay in the demographic transition: amongst other characteristics, the countries in this group show the highest levels of total fertility rate (5.8 in 2015) and adolescent fertility rate (141.7). The lowest

Table 9 Fertility**:** List of 95 analysed countries by cluster of fertility (K-means method)

Cluster	Countries	N
a	Angola, Burkina Faso, Chad, Guinea, Mali, Mozambique, Niger, Sierra Leone, Uganda	9
b	Afghanistan, Benin, Burundi, Cameroon, Central African Republic, Congo Dem Rep, Cote D'Ivoire, Eritrea, Ethiopia, Guinea-Bissau, Gambia, Liberia, Madagascar, Malawi, Mauritania, Nigeria, Sudan, Togo, Tanzania, Yemen, Zambia	21
c	Bangladesh, Cambodia, Congo, Gabon, Ghana, Guatemala, Haiti, India, Kenya, Lesotho, Myanmar, Namibia, Nepal, Papua New Guinea, Rwanda, Swaziland, Zimbabwe	17
d	Egypt, Iraq, Jordan, Morocco, Oman, Pakistan, Saudi Arabia, Syrian Arab Republic	8
e	Argentina, Bolivia, Botswana, Brazil, China, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Honduras, Indonesia, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Philippines, South Africa, Thailand, Uruguay, Venezuela, Vietnam	25
f	Algeria, Bahrain, Chile, Iran, Kuwait, Lebanon, Malaysia, Mauritius, Qatar, Singapore, Sri Lanka, Trinidad And Tobago, Tunisia, Turkey, United Arab Emirates	15

Source: Our elaboration on data of World Bank and United Nations (for details see Appendix Table 10)

contraceptive prevalence is also accompanied by the lowest gender parity index in secondary school enrolment. In addition, only in this cluster does contraceptive use decrease from 2010 to 2015. Moreover, Human Development, income and education indexes assume the lowest levels.

Cluster **b** includes 21 countries (of which 8 are West African and 7 are East African countries) that, generally speaking, assume values similar to those of cluster **a**. However, some differences are apparent: the TFR is significantly lower in all years (4.8 in 2015), and contraceptive prevalence shows an increasing trend, again in 2015 (20.2%), even if it remains at the second lowest level. Female labour force participation, after an increasing trend that peaks in 2005 (71.0%), 10 years shows a sharp decline over the final 10 years.

Cluster **c** represents an intermediate stage on the path toward modernisation. It is geographically very heterogeneous: it includes, besides five Asian countries (India, Bangladesh, Nepal, Cambodia, and Myanmar), nine sub-Saharan African countries, a Central American country (Guatemala), a Caribbean country (Haiti), and one country in Oceania (Papua New Guinea). This cluster shows high level of adolescent fertility rate. It is characterised by the best improvement in contraceptive prevalence (together with cluster **d**) and the highest percentages of female labour force participation (62.7% in 2015). It is also the cluster with the highest reduction in the age at childbearing.

Cluster **d** is quite geographically homogeneous and comprises five West Asian countries, one South-East Asian country (Pakistan) and two North African countries (Egypt and Morocco). As with cluster **c**, it shows the best improvements in contraceptive prevalence in the period 1990–2015. Improvements in female labour participation are also impressive: this was only 15.9% in 1990 but had increased to 56.0% in 2015. In 1990 the age at childbearing was the highest (30.6); in 2015 it continued to be amongst the highest, but with a significant decrease, probably due to an intensity effect, that is, a decline of higher parities.

Cluster **e** is the most populated, comprising 25 countries. They are located in different macro areas, with the largest group (18 countries) in Central and South America. The countries included in this cluster have some demographic characteristics typically representative of an advanced stage of fertility transition: the highest contraceptive prevalence in 2015 (76.2%), the highest gender parity index in secondary school enrolment values, and the second lowest fertility levels. However, it has the lowest age at childbearing (27.1 years).[3]

Cluster **f** includes mostly Asian countries, two North African countries (Algeria and Tunisia), and one Latin American country (Chile). Its demographic characteristics are approaching those of more developed countries but are less advanced in terms of women's status and stage of development, as measured by their scores in the Human Development Index and gender parity index in secondary school enrolment. Of all the clusters, it assumes the lowest fertility levels since 1990. Moreover, its advanced position in the demographic transition is asserted both by the decline in fertility below the replacement level and by the general increase in the age at childbearing in the period 1990–2015.

Figure 2 shows the trajectories of median centres of the clusters for fertility analysis. We observe the temporal dynamic of the clusters with respect to the centre of the axes, representing on average the reference of the overall dynamic. Generally speaking, we observe that the clusters from **a** to **f** spread out respectively from the left to the right of the factorial plane. The different positions and distances of clusters in the factorial plane according to the x-axis are due to persisting differences both in fertility and in socio-economic development levels.

Moreover, the values of clusters change mostly according to component 2 (that is to say, parallel to the y-axis) over the observed period. In other words, the distance of clusters changes in the period 1990–2015 because of the timing of fertility and of labour force participation of women; conversely, it does not significantly converge in terms of fertility levels and the indicators of socio-economic development.

In particular, clusters **a** and **b** have a down-top pattern in the factorial plane, showing a significant delay in fertility behaviours. Cluster **c** and, above all, cluster **d** have a top-down pattern, showing the best performances in terms of labour force participation of women and contraceptive use. Lastly, clusters **e** and **f**, which are in an advanced stage of fertility transition, do not significantly change their position in the factorial plane.

[3] The reduction in the age at childbearing may be due to the decline of third- and higher-order births. At the same time, age at first childbearing should increase according to demographic transition theory. Unfortunately, we do not include mean age by birth order, because these data are not available.

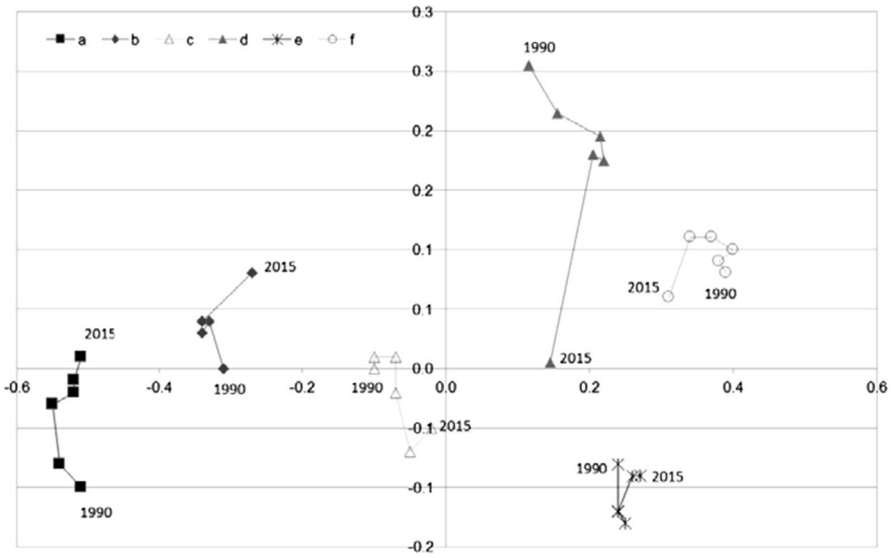

Fig. 2 Differential dynamics of median centres of clusters. Fertility. Factors' scores. Source: Our elaboration on data of World Bank and United Nations (for details see Appendix Table 10)

Discussion

The outcomes of this study make a further contribution to the general discussion on the trends of specific demographic variables regarding fertility and mortality, together with some socio-economic indicators, by answering the previously formulated research hypotheses according to the theoretical and empirical framework. Our results are relevant because they shed light on the heterogeneity amongst clusters in LDCs from a dynamic perspective.

Hp1: Convergent trends of both mortality and fertility levels have been occurring over time across LDCs since the mid-twentieth century

The dynamic analysis of mortality confirms that a large number of LDCs are converging toward a uniform situation, and that certain other countries remain behind. In keeping with Wilson's (2011) observation that the world is divided into a number of blocks, each of which has its own distinctive paths, we identify six clusters of countries. However, a large number of countries (45 out of 95) are grouped into a single cluster, which can be seen as a 'point of arrival' when the convergence dynamic is questioned. When we look at the trajectories of all the clusters, we observe that most tend to converge toward the centre of the axes of the factorial plane and are therefore moving toward more homogeneous conditions. Our results

are therefore in line with those of researchers who have noted the occurrence of rising and converging mortality levels.

The analysis of fertility leads us to different considerations. There is a lower concentration of countries in clusters than in the case of mortality; a lower number of countries (than in the case of mortality) have reached an advanced stage of fertility transition. Moreover, we observe that the temporal dynamic of convergence is not particularly evident. The distance of clusters changes in the period 1990–2015 because of the timing of fertility (age at childbearing) and does not significantly converge in terms of fertility levels. These outcomes confirm Casterline's findings (2001), which noted inter-country and intra-regional variations in the pace of fertility decline. Furthermore, our results are consistent with those of Dorius (2008) and of Wilson and Pison (2004), who found that the trends in fertility variation around the world are not necessarily converging due to the delayed onset of this transition for many LDCs. We agree also with Strulik and Vollmer (2015), who assert that countries characterised by a high fertility regime (essentially sub-Saharan countries) do not show a high level of convergence.

Hp2: Mortality and fertility dynamics have monotonic shapes across LDCs

Not surprisingly, the countries that reached an advanced stage of development do not change their position significantly in the factorial plane and show non-monotonic trends. In addition, specific groups of countries, in particular in sub-Saharan Africa, show non-monotonic temporal trends of mortality, and seem to remain outside the general convergence process. Available data that allowed us to observe the spread of the HIV–AIDS epidemic show two different dynamics. Eleven Central-East sub-Saharan countries experienced a peak of this epidemic during the 'nineties and a subsequent decrease that allowed a movement towards mortality convergence. In contrast, five Southern sub-Saharan countries experienced the largest increase in the prevalence of HIV–AIDS in 2010, with a severe delay in the convergence process. Their most recent improvements started to show positive paths in mortality, but they still have not reduced the gap significantly.

With reference to fertility, the dynamics of clusters on the factorial plane interestingly show quite monotonic trends. In other words, there is no evidence of conjunctural events affecting changes in fertility. The monotonic trends depend on the dynamics of the timing of fertility, which are mainly linked to the increase in female emancipation and participation in the labour force when they are not connected to fertility levels.

The mortality and fertility results reinforce previous research findings (e.g., Casterline, 2001; Dorius, 2008; McMichael et al., 2004; Omran, 1998; Vallin & Meslé, 2004), and update and strengthen them as a result of the analysis of a wide number of countries.

Hp3: LDCs are included in the most disadvantaged/advantaged clusters in terms of mortality and are equally collocated in terms of fertility

Our findings are in line with those of previous analyses (e.g., Berry et al., 2014; Wilson, 2011), demonstrating that the countries under consideration stand at different points and exhibit specific characteristics and paths with respect to mortality and fertility dynamics. Generally speaking (and despite some exceptions, e.g., Guatemala), our results reveal different situations that can be synthesised by the clustering of both phenomena.

However, our results also lead us to conclude that a number of countries have reached low levels of both mortality and fertility and an advanced phase in the demographic transition: 37 countries grouped in the cluster characterised by the lowest fertility levels (that is to say, the clusters **e** and **f**, excluding Bolivia, Botswana, and South Africa) are also grouped in the cluster characterised by the lowest child mortality (cluster **f**). At the same time, the 15 countries with the highest levels of child mortality and maternal mortality (cluster **a**) are grouped in the clusters that assume the highest levels of TFR and adolescent fertility rate (clusters **a** and **b**). In sum, 52 out of 95 observed countries are placed in similar mortality and fertility positions.

Such results support previous research findings (Chesnais, 1997; Coughlin, 2000; Hendi, 2017; Heuveline, 1999; La Croix et al., 2002; Oeppen, 1999) and make an original contribution to the literature by describing the process of global demographic convergence towards a uniform combination of very low fertility and mortality from low to negative growth.

Hp4: A similar convergent trend should occur amongst countries with comparable socio-economic characteristics

We verify whether improvements in fertility and mortality are associated with specific temporal dynamics in 'non-demographic' variables, without testing for a direct causal relation. Our findings corroborate the connection, which has been proven in several of the above-mentioned studies (e.g., Angeli & Salvini, 2018; Mishra et al., 2011), between levels of economic, social, and cultural development and behavioural and demographic characteristics.

This outcome also confirms the results of the analysis performed by Wilson (2001), who highlighted, with regard to convergence in mortality, a consistent link with economic and social development. For fertility the link was less consistent. At the same time, and in accordance with Dorius (2008) and Wang and Sun (2016), our analysis shows that fertility convergence depends mostly on cultural attitudes and decisions that still remain very heterogeneous, because they are strictly connected to the individual sphere, which changes more slowly than economic development indicators.

Confirming the results of Farina and Ortensi (2011), we observe that countries at an advanced economic stage have made the best improvements, while the least

developed ones retain deep pre-existing inequalities, for example in sub-Saharan countries.

Conclusion

Our research contributes to international debates in assessing whether demographic behaviours are indeed converging, or whether marked differences persist across LCDs. Our findings show that convergence in mortality is occurring in most of them, notwithstanding important exceptions. At the same time, we demonstrate that convergence in fertility assumes more delayed and less clear patterns with greater heterogeneity, and it appears to be linked primarily to cultural and behavioural factors that are changing slowly over time. We also conclude that mortality and fertility patterns differ markedly. In particular, mortality trends are influenced by socio-economic development, while fertility dynamics are more linked to the increase in women's emancipation and participation in the labour force. The clusters of countries that showed the worst temporal performance in terms of fertility indicators, also had the worst improvements in the variables related to the condition of women, both with respect to female conditions (such as female labour force participation and gender parity index in secondary school enrolment) and to reproductive behaviour (such as contraceptive prevalence).

Our findings therefore show that the spread of education and female emancipation lead to a decline in fertility and consequently more rapid and equitable development. These issues are inextricably linked to world development. This was addressed by the UN in its Millennium Development Goals in 2000 (UN 2000) and Sustainable Development Goals, defined in 2015 (UN, 2015). In particular, the Sustainable Development Goals placed attention on gender equality, health, and schooling. If some of these goals are achieved by 2030 (particularly those related to reproductive health and women's education), the direct and indirect effects on future convergent demographic trends will be tangible.

In conclusion, we are aware that policies that support economic development, social stability, and poverty reduction are needed (World Bank, 2016). A greater commitment from the international community is required to help the least developed countries catch up with the less developed countries. Our results provide evidence of the specific contexts in which supranational institutions must take prompt action to favour demographic convergent trends and to redirect development policies, in particular with regard to education, the labour market, and female emancipation.

Appendix

See Tables 10, 11, 12, 13 and 14.

Table 10 Data sources and definitions of variables

Source	Definition of variable
The World Bank *World Development Indicators* https://databank.worldbank.org/source/world-development-indicators	Total fertility rate (number of children who would be born per woman if she/they were to pass through the childbearing years bearing children according to a current schedule of age-specific fertility rates)
	Adolescent fertility rate (number of births per 1,000 women ages 15 to 19)
	Contraceptive prevalence, any methods (% of married or in-union women aged 15 to 49 who are currently using, or whose sexual partner is currently using, at least one method of contraception)
	Gender parity index in secondary school enrolment (ratio of girls to boys in secondary education)
	Mortality of children under age five (probability expressed as a rate per 1,000 live births of a child born in a specified year dying before reaching the age of five if subject to current age-specific mortality rates)
	Prevalence of HIV–AIDS (percentage of people tested who were found to be infected with HIV)
	Immunization coverage for DPT3 (diphtheria, pertussis and tetanus—rate of immunization of children aged 12–23 months who have received the specified vaccinations before their first birthday)
	Access to improved sanitation (% of the population using improved sanitation facilities)
World Bank—IBRD-IDA *World Development Indicators* https://datatopics.worldbank.org/world-development-indicators/	Maternal mortality ratio (number of women who die from pregnancy-related causes while pregnant or within 42 days of pregnancy termination per 100,000 live births)
	Labour force participation for women (% ages 15 and older)
	Income index (General National Income per capita expressed as a relative index)
	Education index (measured by combining average adult years of schooling with expected years of schooling for children)
United Nations Population Division *World Population Prospects* https://population.un.org/wpp/	Probability of death at ages 15–60 males (deaths under age 60 per 1,000 alive at age 15)
	Probability of death at ages 15–60 females (deaths under age 60 per 1,000 alive at age 15)

Table 10 (continued)

Source	Definition of variable
United Nations Development Programme *Human Development Reports* http://hdr.undp.org/	Human Development Index (composite index of life expectancy at birth, mean of years of schooling for adults aged 25 years and more and expected years of schooling for children of school entering age, and gross national income per capita)
United Nations Population Division *World Population Prospects: The 2015 Revision—Special Aggregates: Publication List: Ecological—Special* https://population.un.org/wpp/Download/SpecialAggregates/EconomicTrading/	Age at childbearing (mean age of mothers at the birth of their children if women were subject throughout their lives to the age-specific fertility rates observed in a given year)

Table 11 Mortality: correlation matrices

Variable	${}_0m_5$	HIV–AIDS	DPT3	AIS	${}_{45}q_{15}^{M}$	${}_{45}q_{15}^{F}$	HDI	MMR	IC	AYS
Overall correlation matrix (1990–2015)										
${}_0m_5$	1	0.232	−0.735	−0.791	0.703	0.730	−0.877	0.899	−0.745	−0.800
HIV–AIDS	0.232	1	0.003	−0.256	0.652	0.680	−0.221	0.203	−0.180	−0.008
DPT3	−0.735	0.003	1	0.647	−0.453	−0.477	0.648	−0.703	0.528	0.636
AIS	−0.791	−0.256	0.647	1	−0.688	−0.724	0.880	−0.765	0.830	0.769
${}_{45}q_{15}^{M}$	0.703	0.652	−0.453	−0.688	1	0.958	−0.725	0.709	−0.647	−0.528
${}_{45}q_{15}^{F}$	0.730	0.680	−0.477	−0.724	0.958	1	−0.735	0.736	−0.638	−0.536
HDI	−0.877	−0.221	0.648	0.880	−0.725	−0.735	1	−0.830	0.899	0.917
MMR	0.899	0.203	−0.703	−0.765	0.709	0.736	−0.830	1	−0.732	−0.733
IC	−0.745	−0.180	0.528	0.830	−0.647	−0.638	0.899	−0.732	1	0.767
AYS	−0.800	−0.008	0.636	0.769	−0.528	−0.536	0.917	−0.733	0.767	1
Year 1990										
${}_0m_5$	1	0.259	−0.699	−0.806	0.759	0.859	−0.885	0.870	−0.764	−0.813
HIV–AIDS	0.259	1	0.069	−0.286	0.388	0.375	−0.275	0.233	−0.282	−0.132
DPT3	−0.699	0.069	1	0.672	−0.559	−0.647	0.585	−0.694	0.461	0.581
AIS	−0.806	−0.286	0.672	1	−0.741	−0.814	0.848	−0.778	0.807	0.735
${}_{45}q_{15}^{M}$	0.759	0.388	−0.559	−0.741	1	0.937	−0.762	0.814	−0.697	−0.657
${}_{45}q_{15}^{F}$	0.859	0.375	−0.647	−0.814	0.937	1	−0.830	0.914	−0.730	−0.741
HDI	−0.885	−0.275	0.585	0.848	−0.762	−0.830	1	−0.836	0.875	0.905
MMR	0.870	0.233	−0.694	−0.778	0.814	0.914	−0.836	1	−0.726	−0.751
IC	−0.764	−0.282	0.461	0.807	−0.697	−0.730	0.875	−0.726	1	0.733
AYS	−0.813	−0.132	0.581	0.735	−0.657	−0.741	0.905	−0.751	0.733	1
Year 1995										
${}_0m_5$	1	0.269	−0.735	−0.815	0.783	0.852	−0.900	0.908	−0.806	−0.793
HIV–AIDS	0.269	1	0.065	−0.289	0.510	0.536	−0.245	0.224	−0.228	−0.031
DPT3	−0.735	0.065	1	0.738	−0.488	−0.547	0.688	−0.726	0.603	0.685

Table 11 (continued)

Variable	$_0m_5$	HIV–AIDS	DPT3	AIS	$_{45}q_{15}^{M}$	$_{45}q_{15}^{F}$	HDI	MMR	IC	AYS
AIS	−0.815	−0.289	0.738	1	−0.689	−0.750	0.871	−0.761	0.817	0.763
$_{45}q_{15}^{M}$	0.783	0.51	−0.488	−0.689	1	0.964	−0.761	0.781	−0.689	−0.574
$_{45}q_{15}^{F}$	0.852	0.536	−0.547	−0.750	0.964	1	−0.814	0.846	−0.715	−0.638
HDI	−0.900	−0.245	0.688	0.871	−0.761	−0.814	1	−0.835	0.893	0.901
MMR	0.908	0.224	−0.726	−0.761	0.781	0.846	−0.835	1	−0.756	−0.722
IC	−0.806	−0.228	0.603	0.817	−0.689	−0.715	0.893	−0.756	1	0.740
AYS	−0.793	−0.031	0.685	0.763	−0.574	−0.638	0.901	−0.722	0.740	1
Year 2000										
$_0m_5$	1	0.319	−0.774	−0.842	0.743	0.786	−0.913	0.916	−0.801	−0.796
HIV–AIDS	0.319	1	−0.045	−0.288	0.690	0.719	−0.275	0.256	−0.192	−0.021
DPT3	−0.774	−0.045	1	0.736	−0.454	−0.523	0.719	−0.745	0.619	0.664
AIS	−0.842	−0.288	0.736	1	−0.687	−0.736	0.898	−0.780	0.837	0.784
$_{45}q_{15}^{M}$	0.743	0.69	−0.454	−0.687	1	0.957	−0.734	0.728	−0.643	−0.498
$_{45}q_{15}^{F}$	0.786	0.719	−0.523	−0.736	0.957	1	−0.758	0.763	−0.641	−0.521
HDI	−0.913	−0.275	0.719	0.898	−0.734	−0.758	1	−0.839	0.911	0.905
MMR	0.916	0.256	−0.745	−0.780	0.728	0.763	−0.839	1	−0.757	−0.729
IC	−0.801	−0.192	0.619	0.837	−0.643	−0.641	0.911	−0.757	1	0.788
AYS	−0.796	−0.021	0.664	0.784	−0.498	−0.521	0.905	−0.729	0.788	1
Year 2005										
$_0m_5$	1	0.343	−0.715	−0.841	0.710	0.743	−0.897	0.926	−0.763	−0.807
HIV–AIDS	0.343	1	−0.084	−0.281	0.792	0.809	−0.287	0.290	−0.182	−0.035
DPT3	−0.715	−0.084	1	0.653	−0.398	−0.454	0.619	−0.673	0.523	0.580
AIS	−0.841	−0.281	0.653	1	−0.666	−0.694	0.907	−0.814	0.842	0.801
$_{45}q_{15}^{M}$	0.710	0.792	−0.398	−0.666	1	0.966	−0.706	0.706	−0.600	−0.459

Table 11 (continued)

Variable	${}_0m_5$	HIV–AIDS	DPT3	AIS	${}_{45}q_{15}^{M}$	${}_{45}q_{15}^{F}$	HDI	MMR	IC	AYS
${}_{45}q_{15}^{F}$	0.743	0.809	−0.454	−0.694	0.966	1	−0.714	0.733	−0.584	−0.469
HDI	−0.897	−0.287	0.619	0.907	−0.706	−0.714	1	−0.864	0.918	0.913
MMR	0.926	0.290	−0.673	−0.814	0.706	0.733	−0.864	1	−0.778	−0.756
IC	−0.763	−0.182	0.523	0.842	−0.600	−0.584	0.918	−0.778	1	0.799
AYS	−0.807	-0.035	0.580	0.801	−0.459	−0.469	0.913	−0.756	0.799	1
Year 2010										
${}_0m_5$	1	0.275	−0.647	−0.802	0.689	0.722	−0.838	0.848	−0.73	−0.769
HIV–AIDS	0.275	1	−0.089	−0.267	0.739	0.746	−0.245	0.284	−0.174	−0.029
DPT3	−0.647	−0.089	1	0.618	−0.427	−0.452	0.573	−0.603	0.485	0.546
AIS	−0.802	−0.267	0.618	1	−0.690	−0.716	0.903	−0.789	0.845	0.804
${}_{45}q_{15}^{M}$	0.689	0.739	−0.427	−0.690	1	0.965	−0.723	0.709	−0.637	−0.507
${}_{45}q_{15}^{F}$	0.722	0.746	−0.452	−0.716	0.965	1	−0.726	0.744	−0.62	−0.51
HDI	−0.838	−0.245	0.573	0.903	−0.723	−0.726	1	−0.834	0.924	0.925
MMR	0.848	0.284	−0.603	−0.789	0.709	0.744	−0.834	1	−0.741	−0.724
IC	−0.730	−0.174	0.485	0.845	−0.637	−0.620	0.924	−0.741	1	0.814
AYS	−0.769	−0.029	0.546	0.804	−0.507	−0.510	0.925	−0.724	0.814	1
Year 2015										
${}_0m_5$	1	0.242	−0.533	−0.805	0.725	0.779	−0.831	0.896	−0.720	−0.768
HIV–AIDS	0.242	1	−0.002	−0.245	0.690	0.707	−0.208	0.199	−0.142	−0.026
DPT3	−0.533	−0.002	1	0.407	−0.402	−0.353	0.472	−0.437	0.413	0.458
AIS	−0.805	−0.245	0.407	1	−0.693	−0.733	0.885	−0.827	0.815	0.800
${}_{45}q_{15}^{M}$	0.725	0.690	−0.402	−0.693	1	0.954	−0.724	0.718	−0.638	−0.535
${}_{45}q_{15}^{F}$	0.779	0.707	−0.353	−0.733	0.954	1	−0.731	0.768	−0.615	−0.552
HDI	−0.831	−0.208	0.472	0.885	−0.724	−0.731	1	−0.843	0.922	0.935

Table 11 (continued)

Variable	${}_0m_5$	HIV–AIDS	DPT3	AIS	${}_{45}q_{15}{}^{M}$	${}_{45}q_{15}{}^{F}$	HDI	MMR	IC	AYS
MMR	0.896	0.199	−0.437	−0.827	0.718	0.768	−0.843	1	−0.784	−0.748
IC	−0.720	−0.142	0.413	0.815	−0.638	−0.615	0.922	−0.784	1	0.828
AYS	−0.768	−0.026	0.458	0.800	−0.535	−0.552	0.935	−0.748	0.828	1

Table 12 Mortality: median values of variables and values of the first two components by cluster and year

Year/period	${}_{45}q_{15}^{M}$	${}_{45}q_{15}^{F}$	${}_{5}m_{0}$	MMR	HIV	DTP3	AIS	HDI	IC	AYS	Factor 1	Factor 2
Cluster a												
1990	394.3	340.2	214.6	1200	0.7	0.320	10.3	0.293	0.364	0.150	−0.300	0.790
1995	381.4	331.5	205.5	1100	1.7	0.340	10.7	0.295	0.353	0.177	−0.260	0.740
2000	381.0	331.6	181.8	990	1.8	0.430	12.9	0.332	0.344	0.192	−0.160	0.720
2005	365.1	324.6	146.2	760	1.8	0.590	15.3	0.358	0.371	0.254	−0.120	0.610
2010	325.4	282.0	115.9	590	1.5	0.720	18.9	0.405	0.394	0.338	−0.060	0.520
2015	296.6	257.1	93.7	560	1.3	0.800	20.8	0.419	0.402	0.340	−0.030	0.480
1990–2015	−97.7	−83.1	−120.9	−640	0.6	0.480	10.5	0.126	0.038	0.190		
Cluster b												
1990	392.8	329.1	158.9	845	4.6	0.660	14.8	0.342	0.362	0.242	−0.585	0.265
1995	437.0	373.8	163.6	825	7.0	0.580	15.9	0.343	0.362	0.264	−0.880	0.255
2000	469.4	428.8	149.4	755	7.8	0.675	17.4	0.393	0.379	0.309	−0.785	0.290
2005	482.5	451.2	117.9	645	6.5	0.780	19.1	0.423	0.406	0.357	−0.625	0.245
2010	413.7	382.3	89.0	430	5.2	0.845	20.8	0.463	0.433	0.404	−0.490	0.115
2015	375.7	335.0	66.6	445	4.6	0.835	22.2	0.483	0.451	0.418	−0.450	0.085
1990–2015	−17.1	5.9	−92.4	−400	0.0	0.175	7.4	0.142	0.089	0.176		
Cluster c												
1990	447.8	372.7	190.6	580	12.4	0.880	39.9	0.403	0.467	0.375	−1.430	−0.270
1995	532.0	471.7	181.1	630	15.6	0.880	39.6	0.412	0.451	0.456	−1.760	−0.280
2000	620.8	575.7	163.1	680	16.6	0.780	39.2	0.428	0.461	0.486	−1.830	−0.210
2005	578.6	577.6	111.7	570	14.1	0.820	38.6	0.411	0.419	0.493	−1.510	−0.220
2010	473.4	446.8	89.5	460	13.5	0.890	38.8	0.461	0.403	0.533	−1.370	−0.180
2015	344.8	296.6	64.0	470	12.9	0.880	41.0	0.509	0.420	0.543	−1.250	−0.290
1990–2015	−103.1	−76.0	−126.6	−110	0.5	0.000	1.1	0.106	−0.047	0.168		
Cluster d												
1990	327.1	271.5	127.5	630	0.1	0.620	17.6	0.386	0.419	0.276	0.020	0.240
1995	303.1	246.7	114.2	550	0.4	0.580	19.7	0.416	0.437	0.296	0.160	0.220
2000	312.9	256.6	104.8	480	0.8	0.620	23.7	0.442	0.442	0.339	0.200	0.220

Table 12 (continued)

Year/period	$_{45}q_{15}^{M}$	$_{45}q_{15}^{F}$	$_{5}m_{0}$	MMR	HIV	DTP3	AIS	HDI	IC	AYS	Factor 1	Factor 2
2005	291.3	241.7	80.6	330	0.9	0.750	29.5	0.478	0.466	0.373	0.180	0.200
2010	271.5	223.3	66.1	250	0.8	0.820	35.5	0.504	0.515	0.427	0.140	0.210
2015	254.6	205.8	50.8	270	0.6	0.870	40.0	0.510	0.538	0.446	0.150	0.240
1990–2015	−72.5	−65.6	−76.7	−360	0.5	0.250	22.4	0.124	0.119	0.170		
Cluster e												
1990	311.7	237.6	73.5	360	2.2	0.820	39.3	0.578	0.613	0.460	−0.090	−0.150
1995	318.3	254.9	70.2	370	11.5	0.820	46.1	0.580	0.621	0.518	−1.070	−0.570
2000	437.2	394.9	82.9	390	19.9	0.830	51.6	0.556	0.622	0.510	−2.090	−0.910
2005	589.9	567.6	75.2	340	22.8	0.860	54.1	0.569	0.646	0.516	−2.580	−0.840
2010	542.1	524.8	53.8	300	23.1	0.890	56.5	0.610	0.664	0.547	−2.340	−0.730
2015	463.2	412.2	45.4	170	22.2	0.920	57.5	0.628	0.687	0.552	−2.200	−0.870
1990–2015	151.5	174.6	−28.1	−190	20.0	0.100	18.2	0.050	0.074	0.092		
Cluster f												
1990	214.3	139.5	39.4	91	0.1	0.850	79.8	0.619	0.648	0.480	0.340	−0.390
1995	202.7	125.6	30.0	81	0.1	0.900	80.3	0.647	0.672	0.524	0.470	−0.340
2000	193.6	116.5	27.7	65	0.2	0.910	82.7	0.674	0.687	0.553	0.530	−0.300
2005	178.4	99.1	21.9	58	0.2	0.950	85.6	0.702	0.703	0.595	0.490	−0.250
2010	167.2	93.2	17.4	60	0.2	0.950	89.0	0.738	0.727	0.637	0.440	−0.200
2015	158.7	86.8	15.3	50	0.3	0.950	91.5	0.755	0.739	0.650	0.400	−0.190
1990–2015	−55.7	−52.7	−24.1	−41	0.2	0.100	11.7	0.136	0.091	0.170		

Source: Our elaboration on data of World Bank and United Nations (for details see Appendix Table 10)

Table 13 Fertility: correlation matrices

Variable	TFR	$4F_{15}$	CPR	HDI	IC	AYS	GPI	$LFPR^F$	MACB
Overall Correlation matrix (1990–2015)									
TFR	1	0.775	−0.863	−0.832	−0.688	−0.802	−0.689	0.250	0.447
$4F_{15}$	0.775	1	−0.598	−0.704	−0.615	−0.619	−0.499	0.323	−0.084
CPR	−0.863	−0.598	1	0.756	0.585	0.767	0.661	−0.221	−0.552
HDI	−0.832	−0.704	0.756	1	0.899	0.917	0.674	−0.411	−0.294
IC	−0.688	−0.615	0.585	0.899	1	0.767	0.573	−0.474	−0.168
AYS	−0.802	−0.619	0.767	0.917	0.767	1	0.690	−0.246	−0.340
GPI	−0.689	−0.499	0.661	0.674	0.573	0.690	1	−0.175	−0.319
$LFPR^F$	0.250	0.323	−0.221	−0.411	−0.474	−0.246	−0.175	1	−0.061
MACB	0.447	−0.084	−0.552	−0.294	−0.168	−0.340	−0.319	−0.061	1
Year 1990									
TFR	1	0.695	−0.890	−0.745	−0.551	−0.738	−0.615	0.231	0.579
$4F_{15}$	0.695	1	−0.614	−0.636	−0.510	−0.554	−0.440	0.308	−0.068
CPR	−0.890	−0.614	1	0.737	0.532	0.757	0.594	−0.282	−0.570
HDI	−0.745	−0.636	0.737	1	0.875	0.905	0.681	−0.498	−0.329
IC	−0.551	-0.510	0.532	0.875	1	0.733	0.563	−0.580	−0.194
AYS	−0.738	−0.554	0.757	0.905	0.733	1	0.724	−0.331	−0.398
GPI	−0.615	−0.440	0.594	0.681	0.563	0.724	1	−0.206	−0.310
$LFPR^F$	0.231	0.308	−0.282	−0.498	−0.580	−0.331	−0.206	1	−0.025
MACB	0.579	−0.068	−0.570	−0.329	−0.194	−0.398	−0.310	−0.025	1
Year 1995									
TFR	1	0.743	−0.908	−0.803	−0.655	−0.767	−0.704	0.283	0.506
$4F_{15}$	0.743	1	−0.631	−0.668	−0.588	−0.576	−0.497	0.346	-0.086
CPR	−0.908	−0.631	1	0.761	0.604	0.769	0.678	−0.288	−0.564
HDI	−0.803	−0.668	0.761	1	0.893	0.901	0.705	−0.501	−0.316
IC	−0.655	−0.588	0.604	0.893	1	0.740	0.578	−0.534	−0.189
AYS	−0.767	−0.576	0.769	0.901	0.74	1	0.759	−0.327	−0.351
GPI	−0.704	−0.497	0.678	0.705	0.578	0.759	1	−0.205	−0.315
$LFPR^F$	0.283	0.346	−0.288	−0.501	−0.534	−0.327	−0.205	1	−0.042
MACB	0.506	−0.086	−0.564	−0.316	−0.189	−0.351	−0.315	−0.042	1
Year 2000									
TFR	1	0.775	−0.878	−0.842	−0.715	−0.796	−0.662	0.343	0.442
$4F_{15}$	0.775	1	−0.595	−0.705	−0.625	−0.594	−0.496	0.387	−0.099
CPR	−0.878	−0.595	1	0.775	0.599	0.772	0.613	−0.308	−0.562
HDI	−0.842	−0.705	0.775	1	0.911	0.905	0.665	−0.511	−0.305
IC	−0.715	−0.625	0.599	0.911	1	0.788	0.573	−0.552	−0.172
AYS	−0.796	−0.594	0.772	0.905	0.788	1	0.661	−0.338	−0.345
GPI	−0.662	−0.496	0.613	0.665	0.573	0.661	1	−0.219	−0.268
$LFPR^F$	0.343	0.387	−0.308	−0.511	−0.552	−0.338	−0.219	1	−0.045
MACB	0.442	−0.099	−0.562	−0.305	−0.172	−0.345	−0.268	−0.045	1
Year 2005									
TFR	1	0.792	−0.851	−0.854	−0.748	−0.808	−0.766	0.353	0.397

Table 13 (continued)

Variable	TFR	$4F_{15}$	CPR	HDI	IC	AYS	GPI	$LFPR^F$	MACB
$4F_{15}$	0.792	1	−0.558	−0.719	−0.650	−0.614	−0.526	0.399	−0.123
CPR	−0.851	−0.558	1	0.760	0.599	0.782	0.726	−0.286	−0.585
HDI	−0.854	−0.719	0.760	1	0.918	0.913	0.707	−0.507	−0.278
IC	−0.748	−0.650	0.599	0.918	1	0.799	0.639	−0.545	−0.158
AYS	−0.808	−0.614	0.782	0.913	0.799	1	0.740	−0.343	−0.334
GPI	−0.766	−0.526	0.726	0.707	0.639	0.740	1	−0.242	−0.358
$LFPR^F$	0.353	0.399	−0.286	−0.507	−0.545	−0.343	−0.242	1	−0.067
MACB	0.397	−0.123	−0.585	−0.278	−0.158	−0.334	−0.358	−0.067	1
Year 2010									
TFR	1	0.79	−0.812	−0.841	−0.748	−0.788	−0.743	0.343	0.363
$4F_{15}$	0.790	1	−0.537	−0.709	−0.652	−0.614	−0.485	0.403	−0.150
CPR	−0.812	−0.537	1	0.702	0.556	0.726	0.733	−0.238	−0.528
HDI	−0.841	−0.709	0.702	1	0.924	0.925	0.645	−0.476	−0.236
IC	−0.748	−0.652	0.556	0.924	1	0.814	0.572	−0.539	−0.137
AYS	−0.788	−0.614	0.726	0.925	0.814	1	0.670	−0.324	−0.287
GPI	−0.743	−0.485	0.733	0.645	0.572	0.670	1	−0.186	−0.359
$LFPR^F$	0.343	0.403	−0.238	−0.476	−0.539	−0.324	−0.186	1	−0.081
MACB	0.363	−0.150	−0.528	−0.236	−0.137	−0.287	−0.359	-0.081	1
Year 2015									
TFR	1	0.778	−0.794	−0.820	−0.733	−0.766	−0.676	0.189	0.309
$4F_{15}$	0.778	1	−0.507	−0.677	−0.631	−0.593	−0.465	0.263	−0.196
CPR	−0.794	−0.507	1	0.702	0.565	0.718	0.671	−0.074	−0.454
HDI	−0.820	−0.677	0.702	1	0.922	0.935	0.582	−0.182	−0.164
IC	−0.733	−0.631	0.565	0.922	1	0.828	0.520	−0.135	−0.077
AYS	−0.766	−0.593	0.718	0.935	0.828	1	0.597	−0.125	−0.205
GPI	−0.676	−0.465	0.671	0.582	0.520	0.597	1	−0.055	−0.261
$LFPR^F$	0.189	0.263	−0.074	−0.182	−0.135	−0.125	−0.055	1	−0.051
MACB	0.309	−0.196	−0.454	−0.164	−0.077	−0.205	−0.261	−0.051	1

Table 14 Fertility: median values of variables and values of the first two components by cluster and year

Year/period	${}_4F_{15}$	TFR	MACB	CPR	GPI	$LFPR^F$	HDI	IC	AYS	Factor 1	Factor 2
Cluster a											
1990	195.0	7.1	29.1	4.7	0.517	64.4	0.262	0.357	0.140	−0.510	−0.100
1995	193.1	7.0	29.1	6.7	0.556	64.6	0.268	0.344	0.159	−0.540	−0.080
2000	184.7	6.9	29.1	8.1	0.612	66.0	0.313	0.353	0.192	−0.550	−0.030
2005	179.1	6.6	29.0	11.2	0.690	64.4	0.358	0.373	0.253	−0.520	−0.020
2010	161.7	6.2	29.1	16.2	0.703	65.3	0.388	0.406	0.295	−0.520	−0.010
2015	141.7	5.8	29.0	13.9	0.757	58.8	0.413	0.418	0.322	−0.510	0.010
1990–2015	−53.3	−1.3	−0.1	9.2	0.240	−5.6	0.151	0.061	0.182		
Cluster b											
1990	148.0	6.5	29.7	8.7	0.577	66.6	0.369	0.400	0.219	−0.310	0.000
1995	136.0	6.2	29.8	11.4	0.592	69.8	0.368	0.395	0.241	−0.330	0.040
2000	130.2	5.9	29.7	15.7	0.673	70.5	0.392	0.403	0.279	−0.340	0.030
2005	124.3	5.6	29.6	16.9	0.603	71.0	0.432	0.396	0.339	−0.340	0.040
2010	108.4	5.1	29.4	17.7	0.774	70.7	0.459	0.419	0.377	−0.340	0.040
2015	93.0	4.8	29.2	20.2	0.803	56.2	0.479	0.410	0.390	−0.270	0.080
1990–2015	−55.0	−1.7	−0.5	11.5	0.226	−10.4	0.110	0.010	0.171		
Cluster c											
1990	109.5	5.3	29.7	23.2	0.807	67.1	0.428	0.473	0.311	−0.100	0.000
1995	95.6	4.7	29.4	30.9	0.837	66.6	0.459	0.457	0.348	−0.100	0.010
2000	91.4	4.2	29.0	37.0	0.880	65.1	0.447	0.462	0.383	−0.070	0.010
2005	92.0	3.9	28.9	39.3	0.893	61.8	0.482	0.470	0.437	−0.070	−0.020
2010	82.5	3.6	28.5	50.5	0.936	61.5	0.529	0.496	0.488	−0.050	−0.070
2015	73.6	3.3	28.5	53.2	0.979	62.7	0.548	0.528	0.505	−0.020	−0.050
1990–2015	−35.9	−2.0	−1.2	30.0	0.172	−4.4	0.120	0.055	0.194		
Cluster d											
1990	72.1	5.7	30.6	25.2	0.723	15.9	0.563	0.625	0.402	0.115	0.255
1995	60.4	4.9	30.4	34.1	0.839	17.5	0.579	0.606	0.427	0.155	0.215
2000	43.8	4.0	30.2	44.4	0.921	17.7	0.614	0.659	0.461	0.215	0.195
2005	38.2	3.3	29.9	53.5	0.947	18.5	0.640	0.680	0.520	0.220	0.175
2010	37.1	3.1	29.6	53.2	0.884	20.5	0.663	0.707	0.558	0.205	0.180
2015	35.6	3.1	29.6	56.2	0.893	56.0	0.672	0.709	0.572	0.145	0.005
1990–2015	−36.4	−2.6	−1.0	31.1	0.170	40.2	0.110	0.084	0.170		
Cluster e											
1990	86.8	3.5	27.9	53.7	1.043	44.1	0.596	0.625	0.480	0.270	−0.090
1995	83.1	3.1	27.7	59.7	1.080	44.8	0.629	0.653	0.524	0.260	−0.090
2000	79.7	2.7	27.2	65.8	1.034	49.6	0.654	0.654	0.568	0.240	−0.120
2005	71.3	2.5	27.2	72.6	1.063	51.6	0.679	0.666	0.595	0.250	−0.130
2010	62.6	2.4	27.1	74.4	1.062	51.2	0.706	0.686	0.631	0.240	−0.120
2015	60.6	2.3	27.1	76.2	1.065	48.9	0.720	0.722	0.643	0.240	−0.080
1990–2015	−26.2	−1.2	−0.8	22.6	0.022	4.8	0.124	0.097	0.163		
Cluster f											
1990	43.4	3.1	29.2	52.7	1.023	34.1	0.654	0.692	0.482	0.390	0.080

Table 14 (continued)

Year/period	${}_4F_{15}$	TFR	MACB	CPR	GPI	$LFPR^F$	HDI	IC	AYS	Factor 1	Factor 2
1995	31.3	2.7	29.3	60.0	1.036	34.6	0.681	0.728	0.536	0.380	0.090
2000	22.9	2.4	29.3	62.0	1.048	35.5	0.717	0.749	0.619	0.400	0.100
2005	16.7	2.1	29.5	60.2	1.013	37.0	0.731	0.763	0.640	0.370	0.110
2010	14.1	2.0	29.6	62.5	1.035	42.8	0.770	0.784	0.685	0.340	0.110
2015	13.5	1.9	29.7	66.1	1.037	48.7	0.777	0.810	0.687	0.310	0.060
1990–2015	−29.9	−1.1	0.5	13.4	0.013	14.6	0.123	0.118	0.205		

Source: Our elaboration on data of World Bank and United Nations (for details see Appendix Table 10)

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Conflict of interest The authors declare that there is no conflict of interest.

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